Nitrogen, Tillage, and Crop Rotation Effects on Nitrous Oxide Emissions from Irrigated Cropping Systems

Ardell D. Halvorson,* Stephen J. Del Grosso, and Curtis A. Reule USDA-ARS

We evaluated the effects of irrigated crop management practices on nitrous oxide (N_2O) emissions from soil. Emissions were monitored from several irrigated cropping systems receiving N fertilizer rates ranging from 0 to 246 kg N ha^{-1} during the 2005 and 2006 growing seasons. Cropping systems included conventional-till (CT) continuous corn (*Zea mays* L.), no-till (NT) continuous corn, NT corn–dry bean (*Phaseolus vulgaris* L.) (NT-CDb), and NT corn–barley (*Hordeum distichon* L.) (NT-CB). In 2005, half the N was subsurface band applied as urea-ammonium nitrate (UAN) at planting to all corn plots, with the rest of the N applied surface broadcast as a polymer-coated urea (PCU) in mid-June. The entire N rate was applied as UAN at barley and dry bean planting in the NT-CB and NT-CDb plots in 2005. All plots were in corn in 2006, with PCU being applied at half the N rate at corn emergence and a second N application as dry urea in mid-June followed by irrigation, both banded on the soil surface in the corn row. Nitrous oxide fluxes were measured during the growing season using static, vented chambers (1–3 times wk^{-1}) and a gas chromatograph analyzer. Linear increases in N_2O emissions were observed with increasing N-fertilizer rate, but emission amounts varied with growing season. Growing season N_2O emissions were greater from the NT-CDb system during the corn phase of the rotation than from the other cropping systems. Crop rotation and N rate had more effect than tillage system on N_2O emissions. Nitrous oxide emissions from N application ranged from 0.30 to 0.75% of N applied. Spikes in N_2O emissions after N fertilizer application were greater with UAN and urea than with PCU fertilizer. The PCU showed potential for reducing N_2O emissions from irrigated cropping systems.

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*Corresponding author (ardell.halvorson@ars.usda.gov).
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677 S. Segoe Rd., Madison, WI 53711 USA

Agriculture contributes approximately 78% of total N_2O emissions in the USA (USEPA, 2007). Nitrous oxide (N_2O), the principal non-CO_2 greenhouse gas emitted from soils, is produced through nitrification and denitrification (Follett, 2001b; Mosier, 2001). Nitrogen fertilizer input to optimize irrigated crop yields generally increases N_2O production in irrigated cropping systems (Mosier et al., 2006). The net emission of greenhouse gases from farming activities can potentially be decreased by changing crop management practices to increase soil organic carbon (SOC) content (Follett, 2001a) and decrease N_2O emissions (Kroeze et al., 1999). Changing from conventional till (CT) to no-till (NT) practices typically leads to increased SOC content in the surface 7.5 cm of soil, with less change below this depth (West and Post, 2002). The overall balance between the net exchange of these greenhouse gases (CO_2, N_2O, CH_4) constitutes the net global warming potential (GWP) (Robertson and Grace, 2004). Typically, soil C changes relative to N_2O emissions regulate GWP of cropping systems (Mosier et al., 2005, 2006; Robertson et al., 2000). The GWP of N_2O is approximately 296 times greater than that of CO_2 (IPCC, 2001); therefore, it is important to develop methods to reduce N_2O emissions in agricultural systems.

No-till management of soils can potentially offset the GWP from emissions of N_2O in crop production because of its ability to sequester carbon in the soil (Cole et al., 1997; CAST, 2004). Nitrous oxide emissions drive much of the trend in net GWP from agricultural systems (Mosier et al., 2006; Robertson and Grace, 2004). Data sets available for analyzing the impact of N_2O emissions on GWP in irrigated crop production systems are limited. There is a high uncertainty associated with N_2O flux data, which creates a high degree of uncertainty in net GWP estimates (Walters, 2005; Mosier et al., 2006).

Using the DAYCENT ecosystem model, Del Grosso et al. (2002) predicted that during the first few years of NT, net GWP decreases. Over time, as the rate of increase in SOC declines and N_2O emissions increase because of increased N availability in NT soils, the net GWP relative to CT soils is predicted to increase. The model suggests that GWP could be minimized with time by decreasing N fertilizer input to NT systems while maintaining yield. This simulation suggests that

USDA–ARS, 2150 Centre Ave, Bldg. D, Suite 100, Fort Collins, CO 80526-8119.
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Abbreviations: CT, conventional till; CT-CC, conventional-tillage continuous corn; GWP, global warming potential; N_2O, nitrous oxide; NT, no till; NT-CC, no-till continuous corn; NT-CB, no-till corn–barley; NT-CDb, no-till corn–drybean; NT-CSb, no-till corn–soybean; PCU, polymer-coated urea; SOC, soil organic carbon; UAN, urea ammonium nitrate fertilizer.

Table 1. Selected soil chemical and physical properties in the 0- to 15-cm depth of each cropping system at the study site.†

Cropping system	Bulk density	SOC	Total soil N	pH	EC	Sand	Clay
	g cm^{-3}	——g kg^{-1}——			mS cm^{-1}	—g kg^{-1}—	
CT-CC	1.34	11	1.28	7.7	1.00	409	337
NT-CC	1.55	12	1.33	7.7	0.95	397	330
NT-CB	1.45	12	1.27	7.8	0.91	402	321
NT-CDb	1.57	11	1.28	7.8	0.91	402	334

† CT-CC, conventional-till continuous corn; EC, electrical conductivity; NT-CB, no-till corn-barley; NT-CC, no-till continuous corn; NT-CDb, no-till corn–drybean; SOC, soil organic C.

the impact of NT on net GWP decreases over time. In contrast to the Del Grosso et al. (2002) simulation, Six et al. (2004) suggested that GWP would be greater with NT than with CT systems during the early stages of establishing a NT system. They suggested that GWP and N_2O emissions would decrease with time in the NT system as soil aggregation increased and aeration improved in the NT system compared with CT. Additional field measurements of greenhouse gas emissions from NT and CT cropping systems are needed to determine the accuracy of these predictions.

Mosier et al. (2006) reported a sharp rise in N_2O emissions within days after fertilizing with urea-ammonium nitrate (UAN) in conventional-till continuous corn (CT-CC), no-till continuous corn (NT-CC), and no-till corn–soybean (NT-CSb) cropping systems. The N_2O emissions after N fertilization declined to near background levels in about 30 to 50 d and remained there for the rest of the growing season and non-crop period until N fertilization of the next crop. Total N_2O emissions varied from year to year and were higher in CT-CC than in NT-CC when averaged over the 3 yr. Including soybean (*Glycine max* L.) in rotation with corn resulted in greater N_2O emissions during the corn phase of the NT-CSb rotation than in CT-CC and NT-CC rotations. Annual and growing season N_2O emissions increased linearly with increasing rate of N fertilization in the CT-CC and NT-CC systems. Walters (2005) also showed higher N_2O emissions during the corn year after soybean in a corn–soybean rotation in Nebraska.

Venterea et al. (2005) reported that N source influenced N_2O emissions from corn production systems in Minnesota. They observed the greatest N_2O emissions from anhydrous ammonia application, with significantly lower emissions from UAN and lowest emissions from broadcast urea when applied to a corn crop. They also observed no difference in N_2O emissions between CT and NT systems when using UAN but observed slightly higher N_2O emissions from the NT system than from the CT system when using broadcast urea. Mosier et al. (1998) suggested using controlled-release fertilizers to mitigate N_2O emissions from agricultural systems by supplying plants with sufficient N to meet their needs while maintaining a low concentration of mineral N in the soil throughout the growing season to reduce gaseous N loss. Blaylock et al. (2005) reported reduced N_2O emissions from application of a polymer-coated urea (ESN; Agrium Inc., Calgary, AB) when compared with UAN and urea N sources.

The objectives of this study were (i) to obtain N_2O emissions data from CT-CC, NT-CC, no-till corn–barley (NT-CB), and no-till corn–drybean (NT-CDb) irrigated cropping systems during the growing season that could be used to test and improve simulation models for irrigated agricultural systems and (ii) to evaluate the effects of N management on N_2O emissions from irrigated cropping systems.

Materials and Methods

The cropping system by N rate experiments were initiated in 1999 at the Agricultural Research Development and Education Center in northeastern Colorado near Fort Collins (40° 39′ N; 104° 59′ W; 1535 m a.s.l.). The region has a semiarid temperate climate with a typical mean temperature of 10.6°C and rainfall of 383 mm yr^{-1} (average from 1900 to 2005). Corn (*Zea mays* L.), wheat (*Triticum aestivum* L.), barley (*Hordeum distichon* L.), and dry bean (*Phaseolus vulgaris* L.) are the main crops grown in local agriculture. The soil is a Fort Collins clay loam classified as fine-loamy, mixed, superactive, mesic Aridic Haplustalfs. The field was in CT continuous corn for 6 yr before the experiment. Selected chemical and physical properties of the soil sampled in 2002 at the 0- to 15-cm depth are reported in Table 1.

Established cropping systems used for N_2O gas flux measurements in 2005 and 2006 included CT-CC, NT-CC, NT-CDb, and NT-CB. Four N rates (0, 67, 134, and 246 kg N ha^{-1}) were monitored both years in the CT-CC and NT-CC systems. In the other cropping systems, the zero-N and high-N treatments were monitored. The high-N rate was 246 kg N ha^{-1} for corn, 56 kg N ha^{-1} for dry bean, and 112 kg N ha^{-1} for barley. In 2005, half the N fertilizer rate was subsurface band-applied as liquid UAN (containing 32% N, injected about 5 cm below the soil surface in bands spaced 33 cm apart) at corn planting in the NT-CC and CT-CC systems. The second half of the N rate was applied as a surface broadcast polymer-coated urea (PCU) (ESN) in mid-June. The entire N rate was subsurface band-applied as UAN at barley planting in the NT-CB system and at dry bean planting in the NT-CDb system in 2005. All plots were planted to corn in 2006, with PCU being applied at half the established N rate at corn emergence and the second half of the N application as dry granular urea fertilizer at about the V6-V7 corn growth stage followed the next day by 2.5 cm of irrigation water. Both N sources were banded on the soil surface in the corn row. The experimental design for each cropping system was a randomized complete block with three replications.

Mechanical tillage was used in the CT-CC plots (stalk shredder, disk, moldboard plow, disk, roller-mulcher [two passes], land leveler [two passes]) for seed bed preparation. The residue was left on the soil surface of the NT-CC, NT-CB, and NT-CDb plots after harvest. A lateral move sprinkler irrigation system was used to apply irrigation water as needed (determined weekly by the feel method [Klocke and Fischbach, 1998]) during the growing season. Herbicides were used for weed control in all treatments, resulting in the plots being relatively weed free. Additional plot management details for the study are provided in Halvorson et al. (2006) and Halvorson and Reule (2006; 2007).

Measurement of the soil–atmosphere exchange of N_2O began on 5 May 2005 following the same procedures reported by Mosier et al. (2006). Measurements were made one to three times per week during the 2005 and 2006 growing seasons at midmorning of each sampling day. A 10-cm-high vented rectangular aluminum chamber with a sampling port was placed in a water channel that was welded onto an anchor (78.6 × 39.3 × 10 cm) that had been inserted 10 cm into the soil at each sampling site. Anchors were set perpendicular to the crop row so that the crop row and inter-row were contained within each chamber. Duplicate flux measurements were made within each replicate of each treatment plot, for a total of six measurements per treatment. The plants were cut off when they became too tall to fit inside the chambers. Gas samples from inside the chambers were collected by syringe at 0, 15, and 30 min after installation. Gas samples (25 mL to ensure over pressure of sample in the tubes) were then injected into 12-mL evacuated tubes that were sealed with butyl rubber septa and transported to the laboratory in Fort Collins for analysis by gas chromatography. The gas chromatograph used was a fully automated instrument (Varian 3800; Varian, Inc., Palo Alto, CA) equipped with an electron capture detector to quantify N_2O (Mosier et al., 2005). Fluxes were calculated from the linear or nonlinear increase in concentration (selected according to the emission pattern) in the chamber headspace with time (Livingston and Hutchinson, 1995). Estimates of daily N_2O emissions between sampling days were made using a linear interpolation between adjacent sampling dates.

The percent N_2O emissions resulting from the application of N fertilizer was calculated for each treatment. The cumulative growing season N_2O emissions for the zero fertilizer N treatment within a cropping system was subtracted from the growing season N_2O emissions for a given fertilizer rate and year. This difference was divided by the quantity of fertilizer N applied, then multiplied by 100 to obtain percent. A 2-yr average was calculated by averaging the 2005 and 2006 values for each cropping system.

Soil water content (0–10 cm depth) and soil (5 cm depth) and air temperature were monitored at each trace gas sampling event using soil dielectric constant probes (ECHO probes from Decagon Devices, Inc., Pullman, WA) and temperature probes. The maximum and minimum air temperatures measured at the research site are shown in Fig. 1. The date and amount of precipitation and irrigation water applied were also recorded at the site during the growing season. Precipitation was recorded by an automated weather station located within 200 m of the plot area.

Differences in N_2O flux by tillage, N rate, crop rotation, and year were determined by ANOVA using the Analytical Software Statistix8 program (Analytical Software, Tallahassee, FL). All statistical comparisons were made at the $\alpha = 0.05$ probability level unless otherwise stated using the least significant difference method for mean separation. If the ANOVA indicated a significant F value for N rate, a linear function was fitted to the N_2O data using regression functions present in the graphics program SigmaPlot (version 10.0; Systat Software Inc., Richmond, CA).

Results and Discussion

Soil temperatures for each of the sampling dates for each cropping system are shown in Fig. 1. In May, soil temperatures tended to be 1 to 2°C warmer in CT soils compared with NT soils; this trend reversed during the latter part of the growing season. Comparing soil temperatures across N rates in the CT-CC and NT-CC systems, the soil at the 5-cm soil depth was significantly cooler in the NT-CC system during May than in the CT-CC system and warmer during October in 2005 and 2006 (Table 2; significant cropping system × month interaction). When averaged across all months, growing season soil temperatures were not different between the NT-CC and CT-CC systems both years.

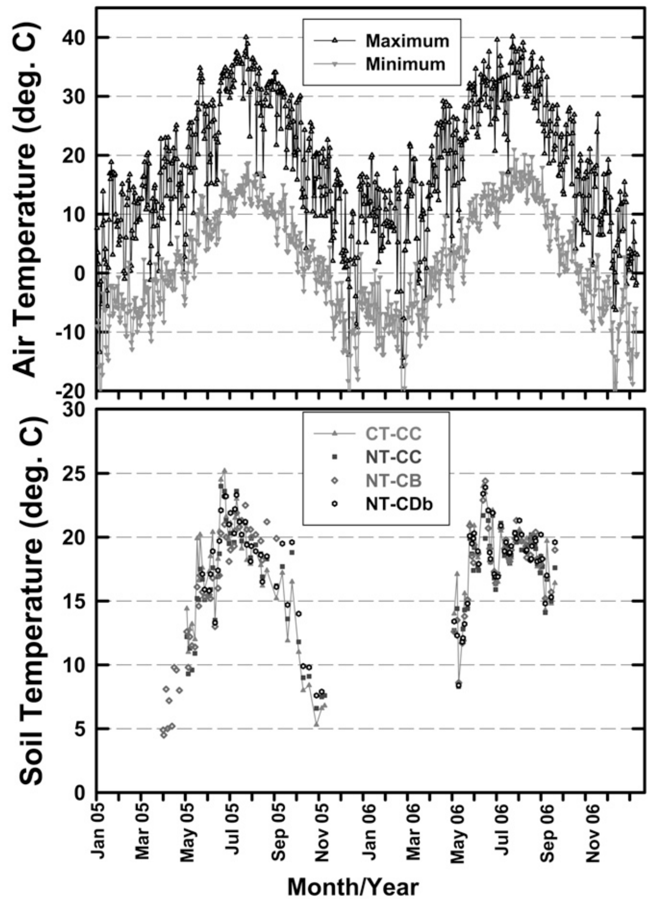

Fig. 1. Daily minimum and maximum air temperature and soil temperature at 5 cm depth, measured at the time of each gas flux measurement, in four cropping system in 2005 and 2006. Conventional till continuous corn (CT-CC), no-till continuous corn (NT-CC), no-till corn–barley (NT-CB), and no-till corn–dry bean (NT-CDb) cropping systems.

Irrigation amount varied with crop grown in 2005 (Fig. 2). In 2005, 25 mm of water was applied to the CT-CC plots before corn planting to ensure germination of the corn due to very dry soil conditions. This resulted in more irrigation water being applied to CT-CC plots than the NT-CC plots in 2005. In 2006, all rotations were planted to corn and received the same amount of irrigation water. We assumed that precipitation was uniform across the experimental plots (Fig. 2).

Volumetric soil water content at each of the sampling dates in 2005 and 2006 is shown in Fig. 3. Soil water content varied with crop rotation, crop grown, and irrigation application in 2005. In 2006, soil water content varied less among cropping systems, with all rotations in corn, than in 2005. However, soil water content tended to be highest in the NT-CDb system early in the growing season in 2006 compared with the other cropping systems. In 2005, soil water content (Table 2) was signifi-

Table 2. Average monthly soil temperature and volumetric soil water content for the conventional till (CT-CC) and no-till (NT-CC) cropping systems in 2005 and 2006 at the study site.

Cropping system	Month	Soil temperature 2005	Soil temperature 2006	Volumetric soil water 2005	Volumetric soil water 2006 average (CT and NT)
		°C	°C	%	%
CT-CC	May	15.3	16.6	22.5	23.5
	June	19.6	19.9	24.1	24.0
	July	20.4	19.2	20.4	23.9
	Aug.	17.4	18.7	26.2	27.0
	Sept.	14.1	13.5	26.7	26.9
	Oct.	7.1	12.2	26.3	22.6
NT-CC	May	13.2	15.3	27.2	
	June	19.3	19.5	27.3	
	July	20.6	19.6	24.0	
	Aug.	18.2	18.6	27.4	
	Sept.	15.5	14.4	26.3	
	Oct.	8.1	12.8	26.8	
	$LSD_{0.05}$†	0.5	0.5	1.2	1.3
	$LSD_{0.05}$‡	0.6	0.5	3.9	–
CT-CC	Average	15.7	16.7	24.4	25.3
NT-CC	Average	15.6	16.7	26.5	24.0
	$LSD_{0.05}$	NS§	NS	NS	NS

† LSD to compare months within a cropping system.

‡ LSD to compare months across cropping systems.

§ NS, not significantly different.

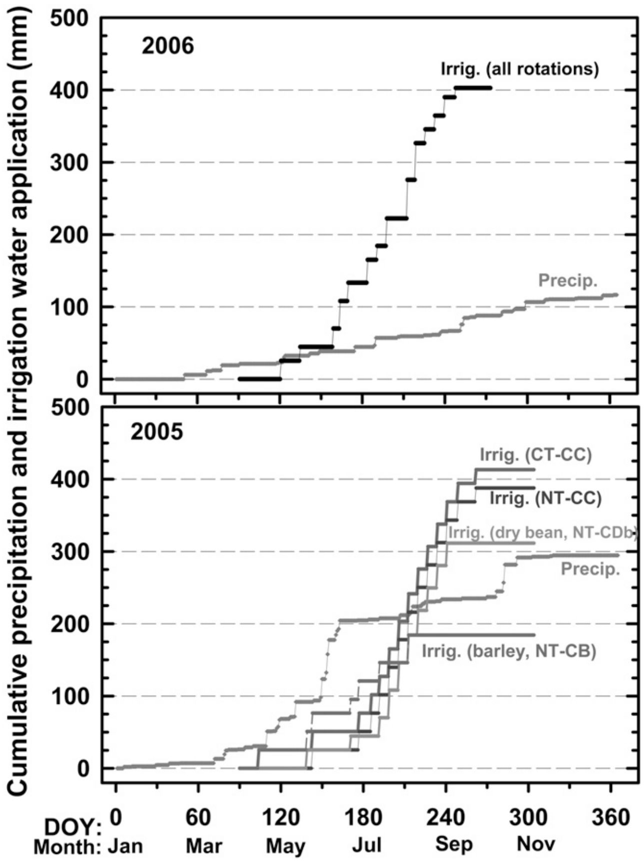

Fig. 2. Precipitation and irrigation at the field study site in 2005 and 2006. Conventional till continuous corn (CT-CC), no-till continuous corn (NT-CC), no-till corn–barley (NT-CB), and no-till corn–dry bean (NT-CDb) cropping systems.

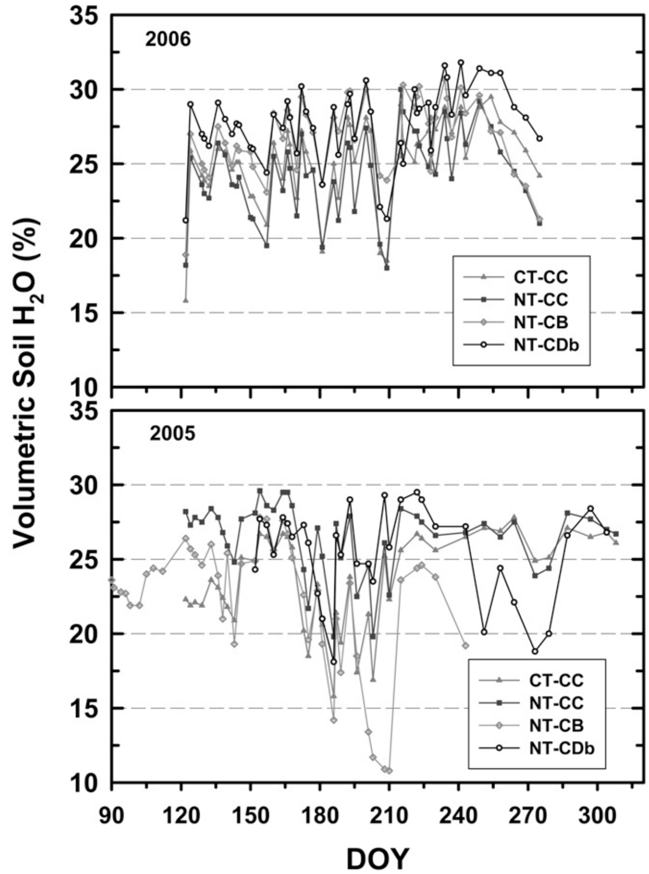

Fig. 3. Volumetric soil water content measured at the time of each gas flux measurement in four cropping system in 2005 and 2006. Conventional till continuous corn (CT-CC), no-till continuous corn (NT-CC), no-till corn–barley (NT-CB), and no-till corn-dry bean (NT-CDb) cropping systems.

cantly greater in the NT-CC system in May than in the CT-CC system, with similar trends in June (significant cropping system × month interaction). In 2006, soil water content varied only with month, being greater in August and September than in the other months of the growing season. Growing season volumetric soil water content for the NT-CB system averaged 22.2% in 2005 when barley was grown and 26.8% in 2006 during the corn phase of the rotation, which was slightly greater than the NT-CC and CT-CC rotations in 2006. Growing season soil water content in the NT-CDb system averaged 25.4% in 2005 during the dry bean phase and 27.8% in 2006 during the corn phase of the rotation. The 2006 average growing season soil water content in the NT-CDb system was slightly greater than that found in the NT-CC and CT-CC systems.

Nitrous oxide fluxes increased within days after the application of UAN in 2005 or urea in 2006 to the CT-CC and NT-CC systems as shown in Fig. 4 for the 0 and 246 kg ha^{-1} N rates. The patterns and trends of daily N_2O fluxes for the 67 and 134 kg N ha^{-1} N rates (data not shown) were similar to, but of lower magnitude than, those shown for the high N rate in Fig. 4. The N_2O flux patterns from the high N rate during the corn phase of the NT-CB and NT-CDb systems in 2006 (data not shown) were also similar to those shown in Fig. 4. In all rota-

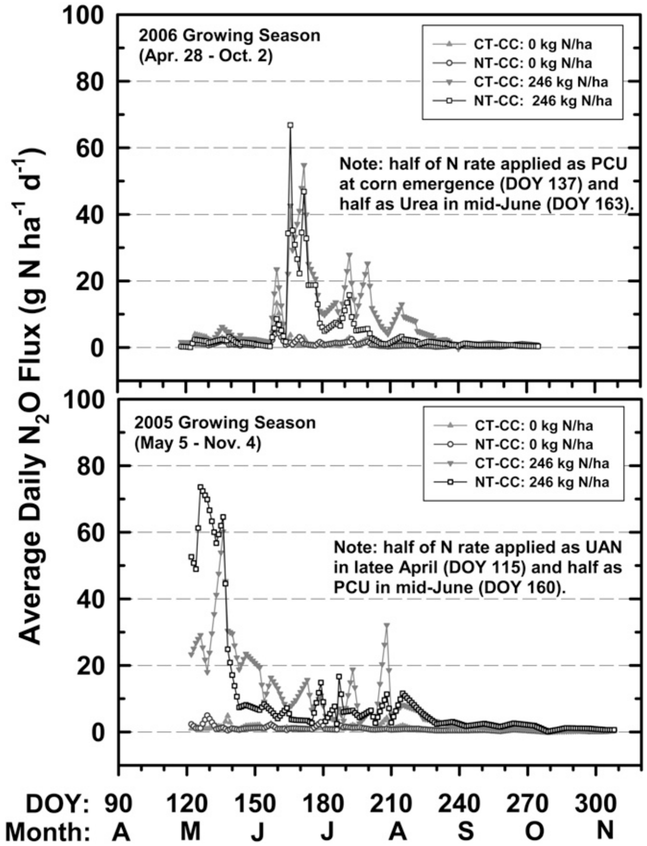

Fig. 4. Nitrous oxide fluxes during 2005 and 2006 growing seasons in the unfertilized and high N rate conventional till continuous corn (CT-CC) and no-till continuous corn (NT-CC) treatments.

tions, N_2O fluxes were highest the first 30 d after N fertilization with UAN or urea and then declined toward background levels.

After the application of the PCU fertilizer on 9 June 2005 to the CT-CC and NT-CC systems, there was not a sharp rise in N_2O emissions as observed for the UAN application applied on 25 Apr. 2005 (Fig. 4). In 2006, the PCU fertilizer was applied shortly after corn emergence (17 May) with little or no increase in N_2O emissions above the background level until the application of the urea N source on 12 June followed by irrigation on 13 June, which was followed by a sharp rise in N_2O emissions (Fig. 4). Although application of two different N sources to the same N treatment plots both years makes it difficult to separate the N_2O fluxes resulting from each N source, these preliminary N_2O flux data indicate that the PCU N source may have the potential to reduce N_2O emissions in irrigated cropping systems.

As a follow-up to the 2005 and 2006 studies, urea and PCU were applied at the same N rate to separate plots in 2007 shortly after corn emergence on 18 May followed by 1.3 cm of irrigation water on 21 May in the NT-CC and CT-CC systems. In 2007, the trend was for lower, but not significant, N_2O growing season emissions with PCU than with urea in the CT-CC system (unpublished data). Lower growing-season N_2O emissions were observed in the NT-CC system than the CT-CC system for both N sources, with significantly ($\alpha = 0.05$) lower N_2O emissions with PCU than with urea (unpublished data). Based on the 2007 N_2O emission peaks during the growing season for each N source, the N_2O emis-

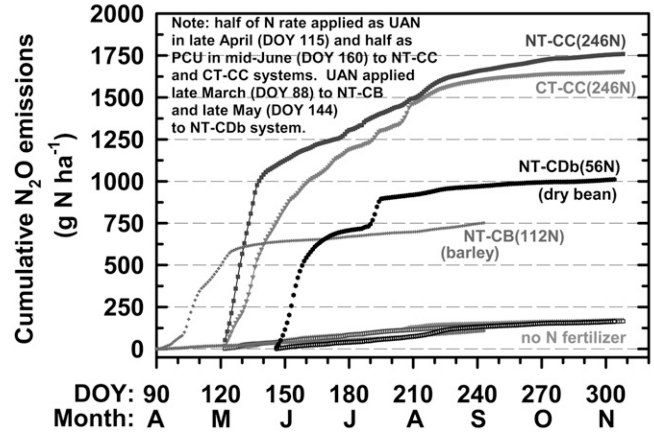

Fig. 5. Total cumulative growing season N_2O emissions during 31 Mar. to 4 Nov. 2005 for the low and high N rates in four cropping systems. Conventional till continuous corn (CT-CC), no-till continuous corn (NT-CC), no-till corn–barley (NT-CB, crop = barley), and no-till corn–dry bean (NT-CDb, crop = dry bean) cropping systems.

sions peaks late in the 2005 and 2006 growing season probably resulted from the PCU N source. These results are consistent with the lower N_2O emissions reported by Blaylock et al. (2005) from the ESN polymer-coated urea compared with other N sources.

Differences in N_2O flux intensity during the two growing seasons are evident in Fig. 5, 6, and 7, which show significantly greater cumulative N_2O emissions in 2005 than in 2006 for the NT-CC and CT-CC rotations. This variation in growing season N_2O emissions is consistent with the variation in yearly N_2O fluxes reported by Mosier et al. (2006). The CT-CC system had significantly greater ($\alpha = 0.10$) cumulative N_2O emissions (709 g N ha^{-1}) during the growing season than the NT-CC system (612 g N ha^{-1}) when averaged over both years and the four N rates. There was a significant N rate × year interaction for cumulative growing season N_2O emissions when comparing the NT-CC and CT-CC systems across N rates and years. This interaction resulted from greater growing season cumulative N_2O emissions in 2005 than 2006, with similar levels of N_2O emissions between CT-CC and NT-CC

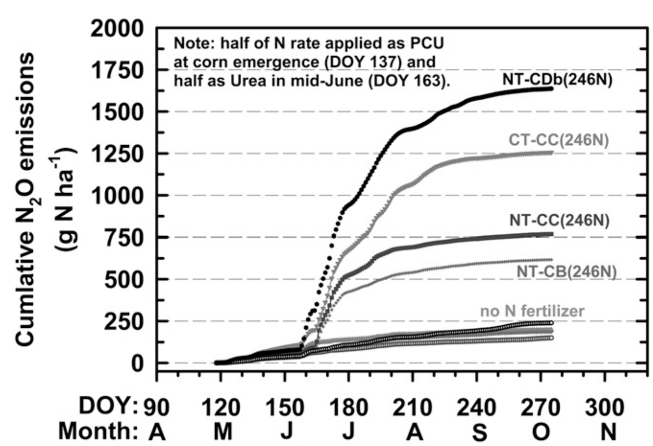

Fig. 6. Total cumulative growing season N_2O emissions during 28 April to 2 Oct. 2006 for the low and high N rates in four cropping systems. Conventional till continuous corn (CT-CC), no-till continuous corn (NT-CC), no-till corn–barley (NT-CB), and no-till corn–dry bean (NT-CDb) cropping systems, with all systems in corn.

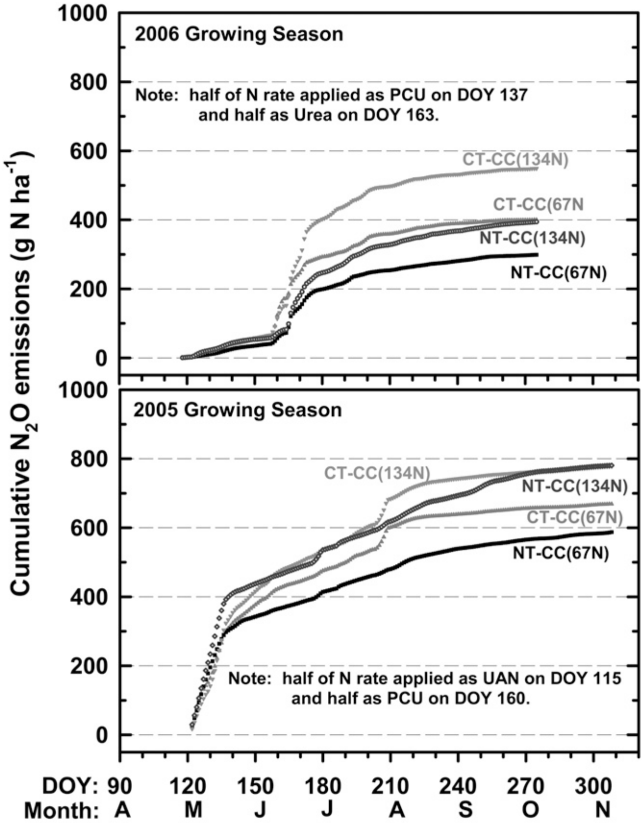

Fig. 7. Total cumulative growing season N_2O emissions during 5 May through 4 Nov. 2005 and 28 Apr. through 2 Oct. 2006 for the conventional till continuous corn (CT-CC) and no-till continuous corn (NT-CC) medium N rate treatments.

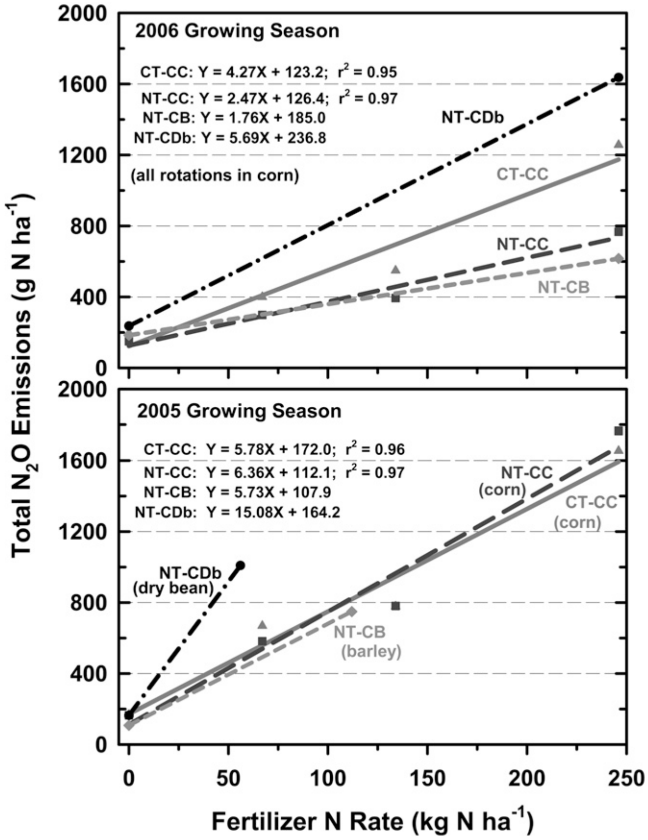

Fig. 8. Total growing season N_2O emissions from four cropping systems as a function of N fertilizer rate during 31 Mar. through 4 Nov. 2005 and 28 Apr. through 2 Oct. 2006. Conventional till continuous corn (CT-CC), no-till continuous corn (NT-CC), no-till corn–barley (NT-CB), and no-till corn–dry bean (NT-CDb) cropping systems.

in 2005 but higher total N_2O emissions with CT-CC than with NT-CC in 2006 with fertilizer N applied and similar levels of cumulative N_2O emissions with no fertilizer N applied (Fig. 5–7). The higher level of N_2O emissions with the NT-CC system in 2005 compared with 2006 may have resulted from the wetter soil conditions during May and June in 2005 than in 2006 along with cooler soil temperatures (Table 2). None of the other interactions was significant when comparing the NT-CC and CT-CC systems for both years. In 2005, cumulative N_2O emissions were slightly greater with 56 kg N ha^{-1} applied to the dry bean crop in the NT-CDb rotation than with 112 kg N ha^{-1} applied to the barley crop in the NT-CB rotation.

In 2005 and 2006, a separate ANOVA was done for each year (except for the zero N rate, which was compared across years) because of the different N rates and crops grown (barley in NT-CB rotation and dry bean in NT-CDb rotation in 2005 and only corn in 2006). With no N applied, the cumulative N_2O emissions averaged over both growing seasons were in the following order: NT-CDb ≥ CT-CC = NT-CC = NT-CB (200, 183, 157, and 146 g N ha^{-1}, respectively) ($P = 0.055$). The inclusion of the dry beans in the NT-CDb system resulted in a slightly greater background level of N_2O emissions compared with the other rotations when averaged over the 2 yr. Comparing cumulative N_2O emissions from the high N rate of all rotations in 2006, the NT-CDb rotation had a significantly ($P = 0.039$) greater emission (1637 g N ha^{-1}) than NT-CC (768 g N ha^{-1}) and NT-CB (616 g N ha^{-1}), with the CT-CC system (1257 g N ha^{-1}) having equal cumulative N_2O emissions to NT-CDb and NT-CC. The NT-CC emissions were not significantly different from the NT-CB emissions.

The influence of N fertilization rate on cumulative N_2O emissions during the growing season is shown in Fig. 8. We assumed that the response in cumulative N_2O emissions to N fertilization would be linear for the NT-CB and NTCDb systems based on the linear response shown with multiple N rates for NT-CC and CT-CC systems and the 3 yr of data showing a linear relationship reported by Mosier et al. (2006). Except for the NT-CDb rotation (dry bean crop) in 2005, all cropping systems had similar levels of total growing-season N_2O emissions with increasing N rate. In 2006, the NT-CC and NT-CB systems showed a smaller increase in cumulative N_2O emissions with increasing N rate than the CT-CC and NT-CDb systems. The higher level of N_2O emissions from the NT-CDb system than from the other systems is consistent with the higher level of N_2O emissions for the NT corn–soybean rotation reported by Mosier et al. (2006). Including dry bean in the rotation resulted in higher N_2O emissions during the corn year of the rotation, similar to that reported for corn following soybean by Mosier et al. (2006) and Walters (2005).

The 2-yr average N_2O emissions from each cropping system as a percent of N fertilizer applied varied significantly ($P = 0.04$) with crop rotation in the following order: NT-CDb (0.75%) ≥ CT-CC (0.52%) = NT-CC (0.45%) = NT-CB (0.30%). These N_2O emissions from the application of a unit of N fertilizer for these irrigated cropping systems are slightly lower than the 1% being used by IPCC (2006) to estimate N_2O emissions from N fertilizer application. Bouwman et al. (2002) reported that global mean fertilizer-induced N_2O emissions amounted to 0.9% of N applied. Adviento-Borbe et al. (2007) reported a range of 0.4 to 1.5% N_2O emissions per unit of N fertilizer applied in 2004 and 2005 from continuous corn and corn–soybean rotations in Nebraska. The percent of N_2O emissions from N fertilizer application in this study tended to be greater within the NT-CDb system than the other cropping systems. The possible reduction in N_2O emissions with the use of the PCU N fertilizer may be partially responsible for the lower N_2O emissions per kg of N applied in this study. Additional work is needed to verify the effectiveness of PCU in reducing N_2O emissions in irrigated cropping systems. The authors initiated a study in 2007 to compare N_2O emissions from several N sources at this research site. The N_2O data from these studies are being used to test and improve the DAYCENT model for irrigated production systems (Del Grosso et al., 2008).

Summary

Nitrous oxide emissions during the 2005 and 2006 growing seasons were measured within four irrigated cropping systems (CT-CC, NT-CC, NT-CB, and NT-CDb) that had several N fertilizer application rates. When UAN or urea was applied, N_2O emissions increased significantly within 2 to 4 d of N application compared with nonfertilized treatments. Increased N_2O emissions from UAN and urea application occurred mostly during the first 30 to 40 d after N fertilizer application, with N_2O fluxes declining to near background levels thereafter. In contrast, when the PCU fertilizer was applied, only a small increase in N_2O emissions was observed later in the growing season. This may show a potential of PCU fertilizers for reducing N_2O emissions in irrigated cropping systems. Total growing season N_2O emissions varied with year and tillage system but were proportional to the amount of N applied. The CT-CC corn system had significantly greater cumulative N_2O emissions when averaged over the two growing seasons and N rates than the NT-CC system. Emissions of N_2O increased significantly with increasing N rate in all cropping systems. Emissions of N_2O were generally greater from the NT-CDb system than from the other cropping systems in this study when compared at similar N rates. The amount of N_2O emitted from a unit of N fertilizer ranged from 0.30 to 0.75% in this study. The use of PCU seems to show the potential for reducing N_2O emissions in irrigated systems, but more research is needed to verify this observation.

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